Recent Activity in FNAL Detector R&D

AEM
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May 6, 2013

Detector R&D Budget Supports 36 FTE of Engineering and Technical Support on a Wide Set of Project Portfolios

PORTFOLIO	TASK	DESCRIPTION
Collider Detectors	Tracking ASIC R&D	Development of ASIC's for silicon detector readout and fast triggering capability
	Tracking Mechanical	Mechanical support and cooling designs for lepton colliders
	Calorimetry	Dual readout techniques, SiPM characterization
	psec Time-of-Flight	Contribution to the LAPPD phototube program at ANL
	Scintillators	Scintillator extrusion and testing for community
Liquid Argon	20 Ton Demonstrator	Large scale liquid Argon purification test
	Materials Test Stand	Testing materials for LAr TPC
	Cold Electronics	Cold electronics in conjunction with BNL (digital) and MSU (analog)
	Low backgrounds	Develop capability for producing low background Ar for dark matter community
	Liquid Argon in Test Beam	Support for cryogenic detector capability in new MCenter beamline
Cosmic Frontier	CCD R&D	Low noise readout & dark matter & neutron imaging
	MKIDs	Development of high speed, low resolution wide field spectroscopy
	Bubble Chamber	New bubble chamber fluids (C3F8) for spin-dependent dark matter
	Laser interferometry	Support of high finesse laser lab for space-time measurements
	Solid Xenon	New type of dark matter/axion detector
DAQ	Sensor DAQ	Radiation hardness testing in new sensors for community
	Optical DAQ	Large collaboration to work on multi-Gbit optical links
	mTCA and ATCA	Evaluation of newest data-flow architecture
Facilities, Outreach	Tools	Upgrading R&D tools as needed
	ASIC support	Supporting software for ASIC development
	Test beam equipment	Pixel telescope support for FNAL Test Beam Facility
	Mcenter test beam	Development of second test beam line
	General Initiatives	New program to support University initiatives
	Detector School	EDIT 2013 & ICFA graduate student schools

(Each portfolio has a manager in the Detector Advisory Group)

Progress in Liquid Argon R&D: Long Bo in LAPD

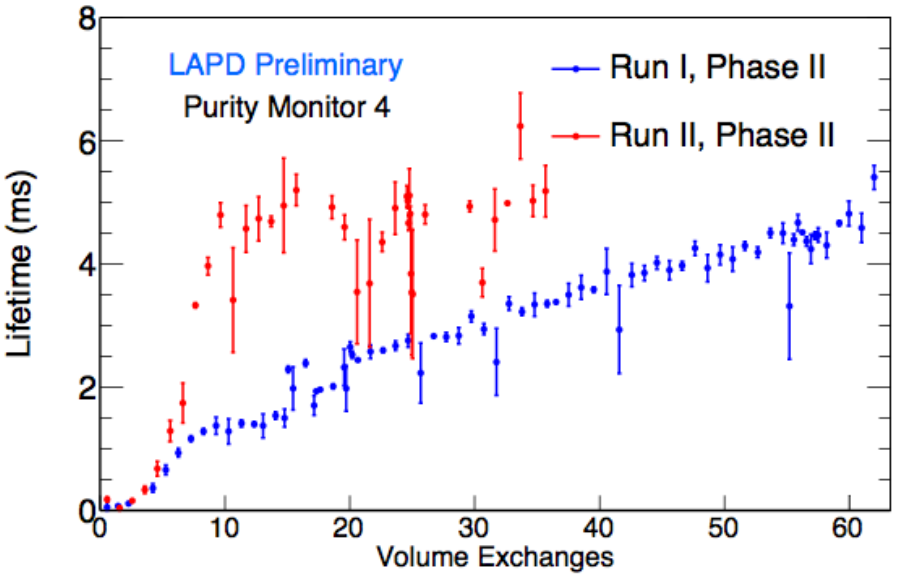
- 'Liquid Argon Purity Demonstrator' has, indeed, demonstrated high purity in a non-evacuated 30 ton volume.
- Now instrumented with the longest TPC in the U.S. – 'Long Bo'

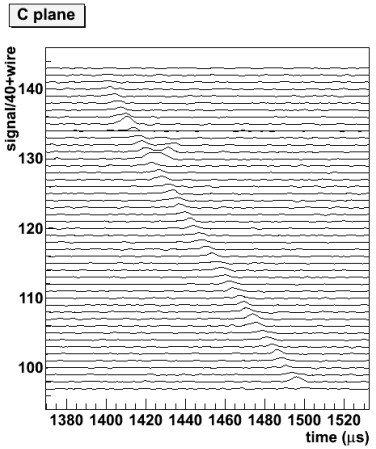
Long Bo TPC In liquid electronics from MSU

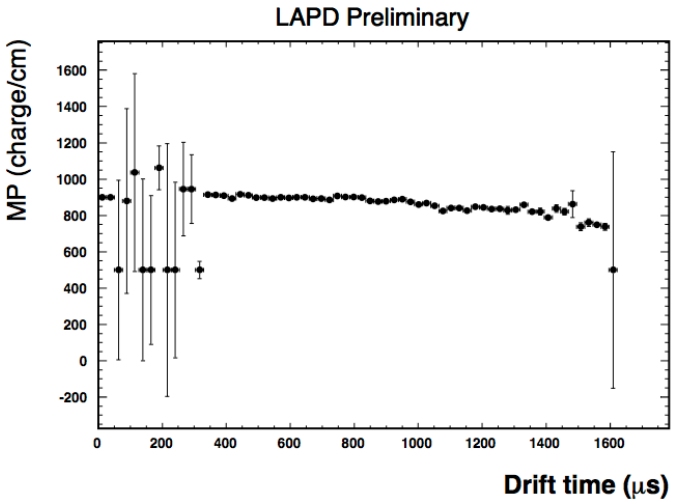
LAPD (in PC4) - 30 tons LAr

LAPD+LongBo Results

- Trigger on cosmic rays
- Purity improvement with time, now >4 msec
- Less than 20% decrease in dQ/dX after 1 meter drift

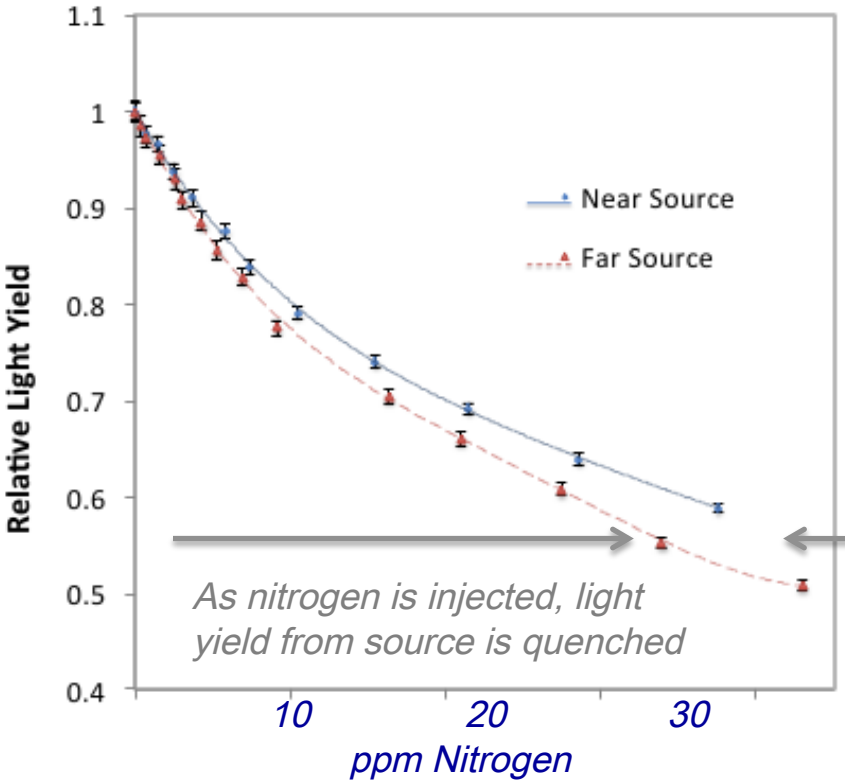






Light Attenuation due to Nitrogen Contamination in Liquid Argon

PRELIMINARY

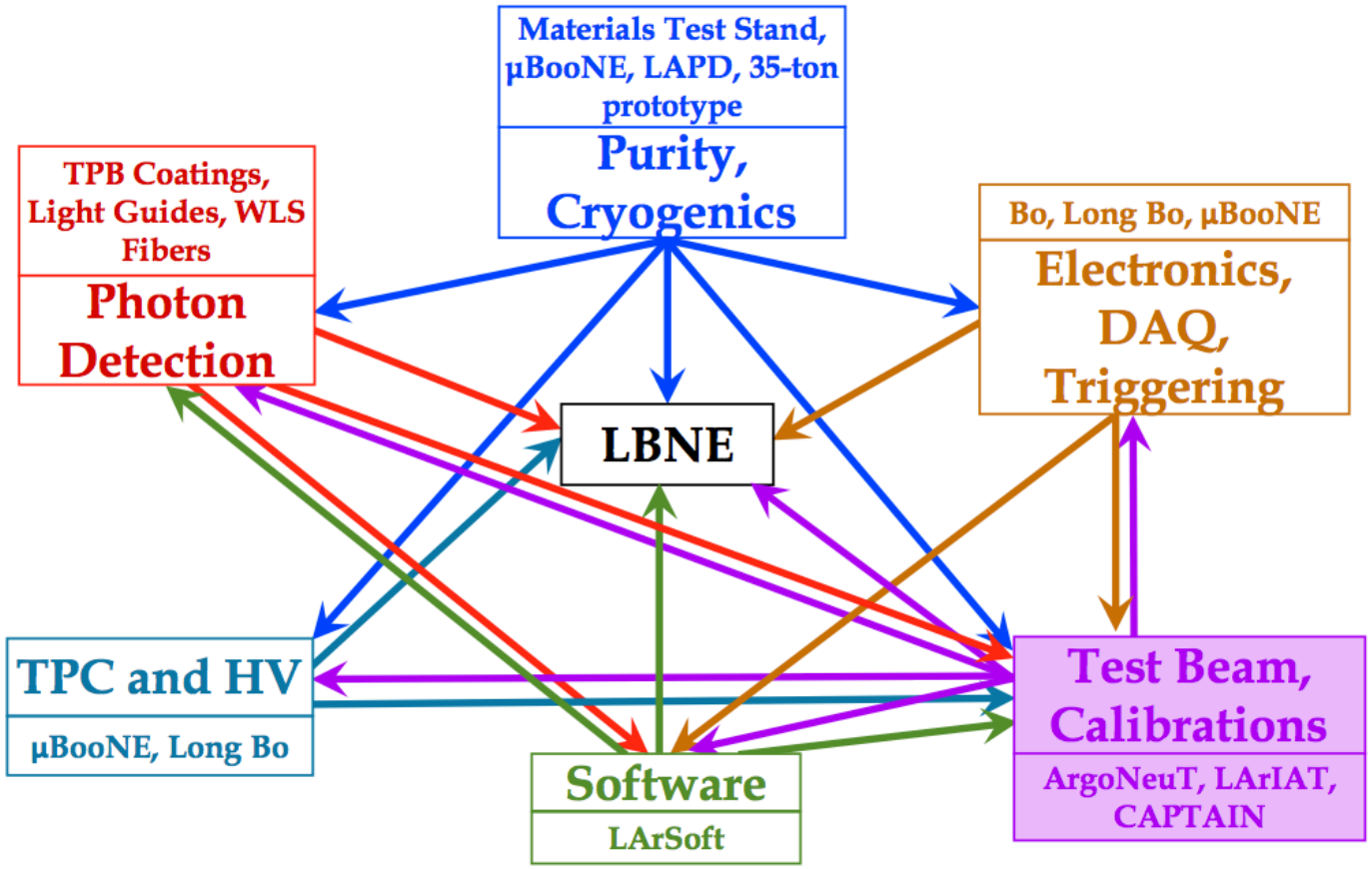


Bo has been setup as a training ground for one slice of the MicroBooNE optical system

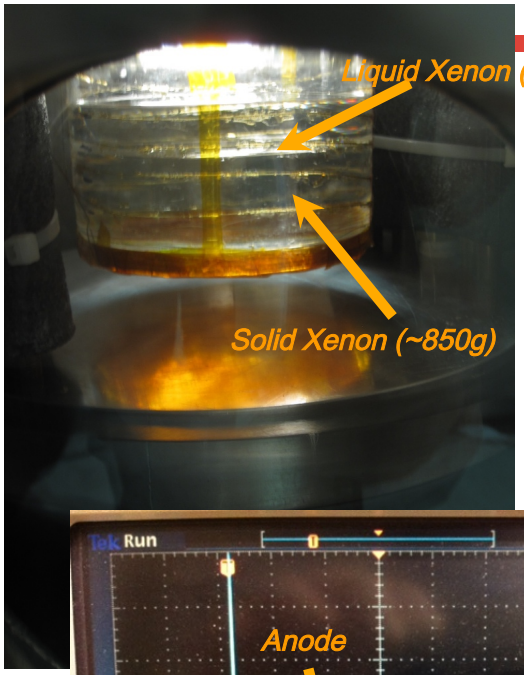
The divergence of these two curves shows the nitrogen light absorption effect.

Final analysis and extraction of absorption cross section in progress.

Alan Stone, of DOE, emphasized at his Intensity Frontier talk about how central detector R&D has been to the success of MicroBoone and LBNE



Solid Xenon for Dark Matter and Double Beta Decay



Phase-1: Produce solid xenon

~kg crystal clear solid xenon was successfully made (2010)

Phase-2: Measure properties of solid xenon

a. Automate solid xenon fabrication – accomplished

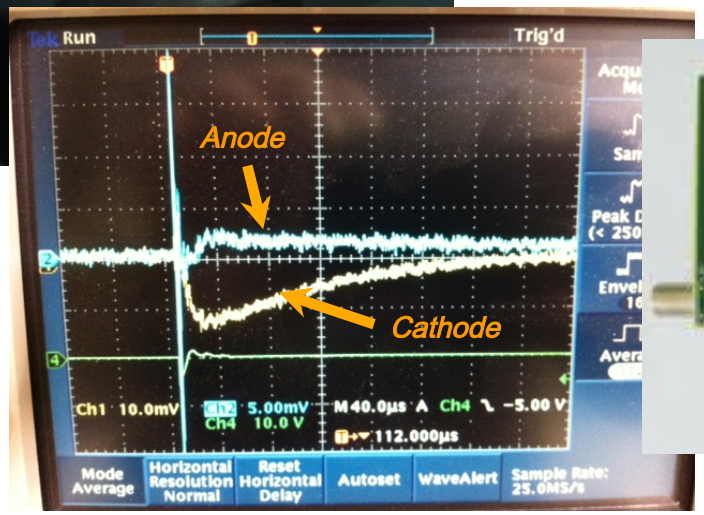
b. Scintillation light measured – investigating normalization

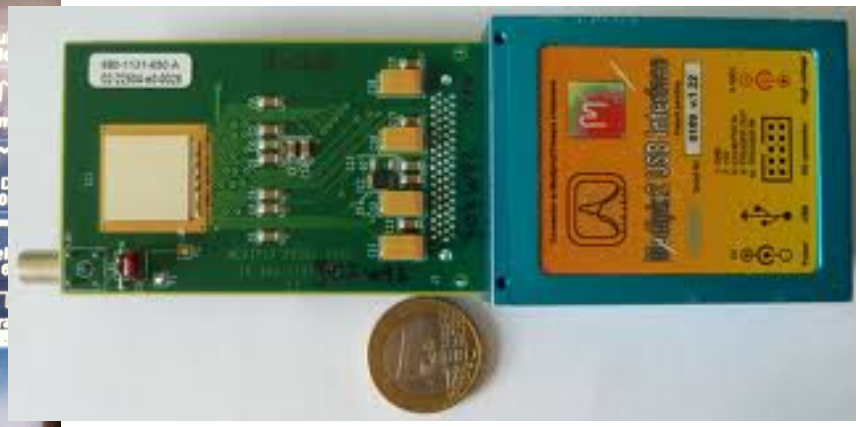
c. Electron drift in solid xenon measured, but need to improve yield

d. Particle track measurement using Timepix

- Collaboration with University Erlangen

- Low temperature test (77K) of the Timepix done

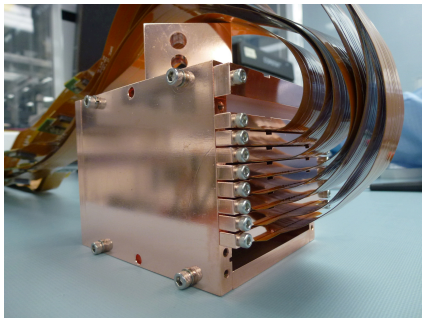


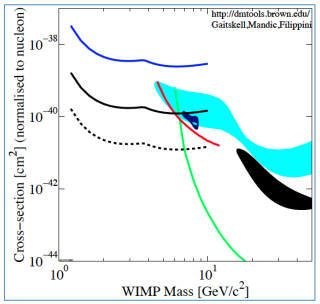


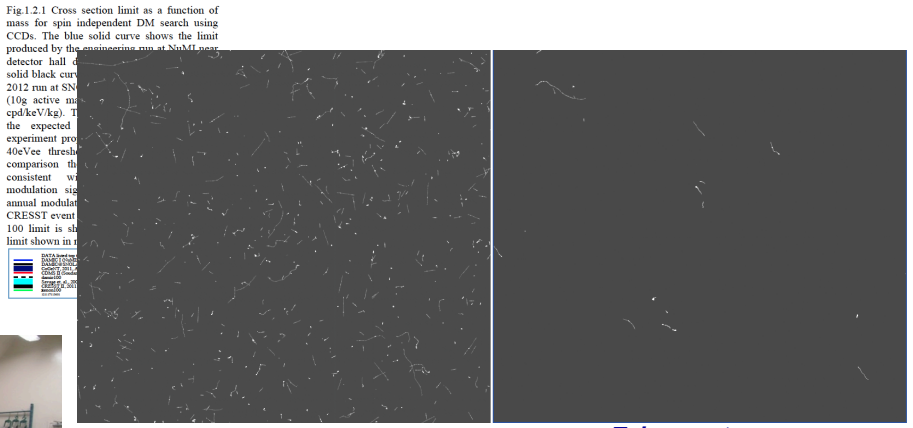
Timepix
Low temperature test(77K)
(U.Erlangen)

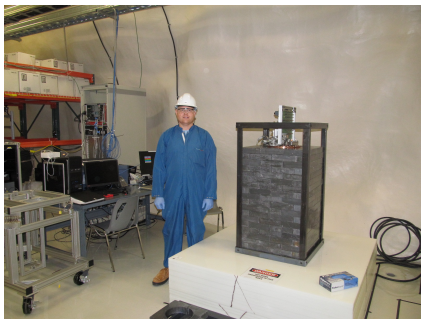
Progress in Cosmic Frontier R&D: DAMIC - A New Type of Dark Matter Detector

- Uses DES CCD's to search for low mass dark matter
- Installation in SNOLAB shows significant reduction in background
- Transitioned from detector R&D to project status this fiscal year









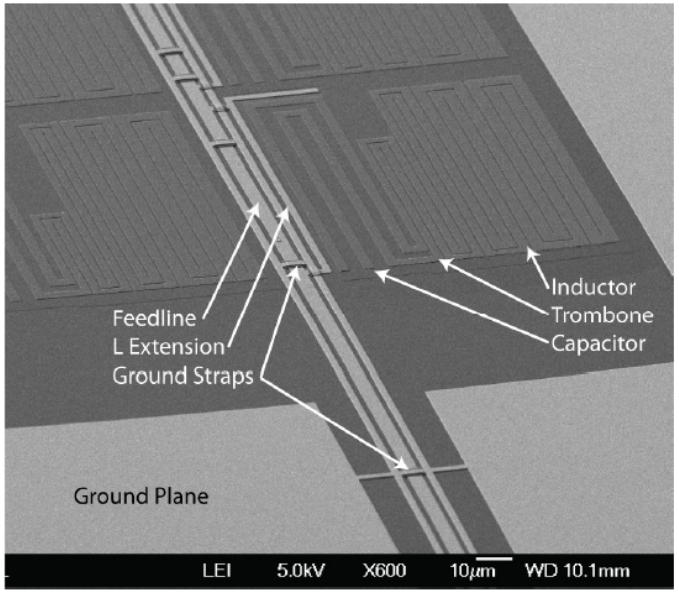
5 hrs at surface (FNAL)

5 hrs at 68000ft UG (SNOLAB) …with partial shield

Another example of transition from R&D to project

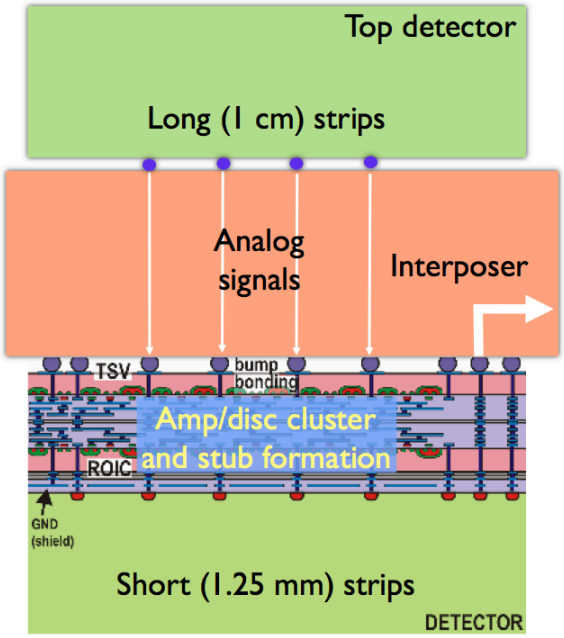
MKIDS='Microwave Kinetic Inductance Detectors'

- A relatively new cryogenic technology that can provide real-time photon energy measurements for a wide variety of experiments, including galactic surveys and X-ray science
- Goal is to use Fermilab expertise in cryogenics, CCD's and RF to create an array of 10,000 pixels, monitored by one, or a few, RF feed lines



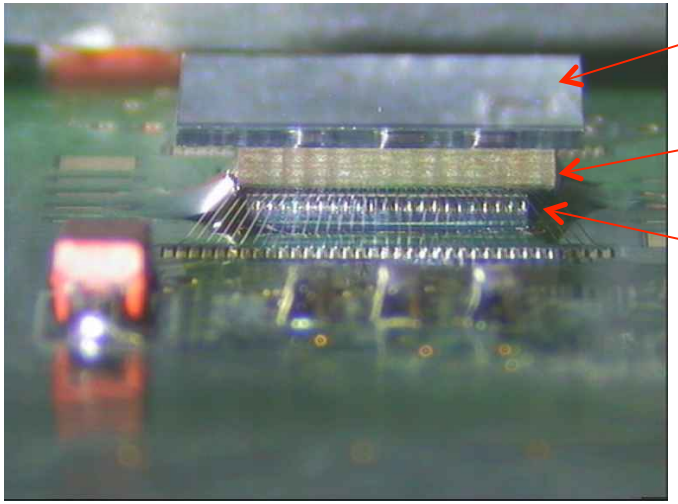
Adiabatic Demagnetization Refrigerator (ADR) commissioning 4/24-4/26
33 mK : Coldest temperature achieved at FNAL?

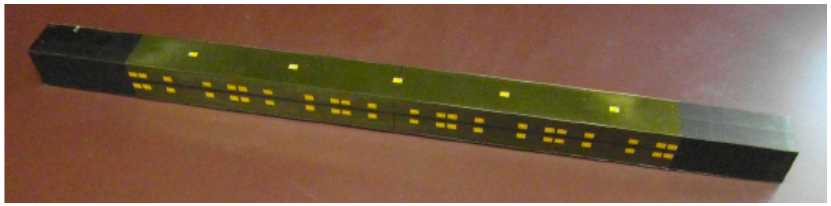
Progress in Energy Frontier R&D: 3D I.C's, CAM's, and 65 nm Design



VICTR = 'Vertically Integrated CMS Trigger'

Top sensor analog information flows through interposer to IC mounted on bottom
Long strips on top provide r-phi to minimize number of interposer connections
Short strips on the bottom provide Z resolution
ROIC amplifies, discriminates. forms stubs and manages pipeline
- all correlations are local



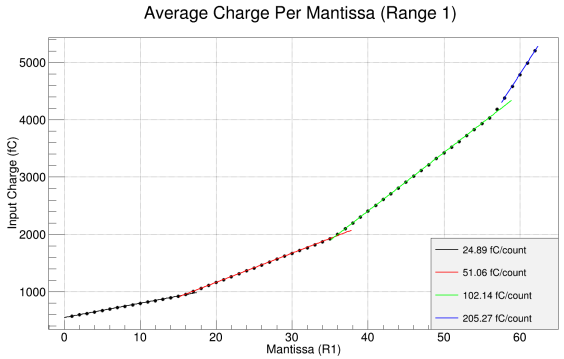


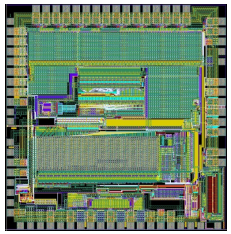
Collaborating with: SLAC, BNL, UC Davis, Cornell
Companies: AllVia, Tezzaron, Ziptronix, VTT

Integrated Circuits (cont.)

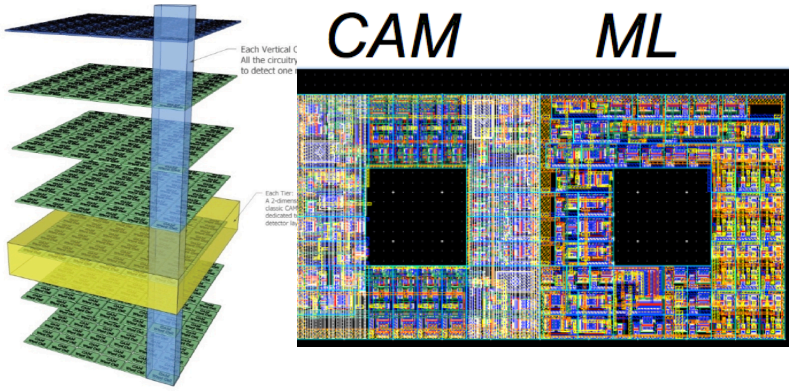
QIE10: a charge integrating, floating point digitizer for CMS/ATLAS

- 40 MHz dead-timeless operation
- Very high dynamic range: 3 fC to 350 pC (equivalent to ~17 bits)
- “Floating point” gives approx. constant resolution
- Programmable threshold TDC with 500 ps binning
- First full-chip prototype is fully functional
- Future QIE11 for SiPMs





Pre-production prototype with 0.35μm SiGe process was delivered at end of March 2013. Bench and larger quantity tests underway



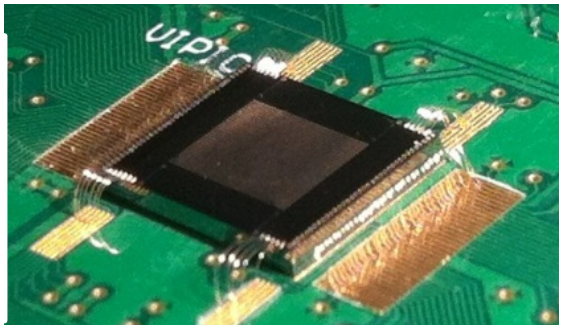
Status of VIPRAM:

- Novel concept for using content addressable memory cells (CAM) as an extremely compact and fast back end trigger lookup.
- Circuit topology oriented in a 3 Dimensional framework
- Chips expected in May 2013

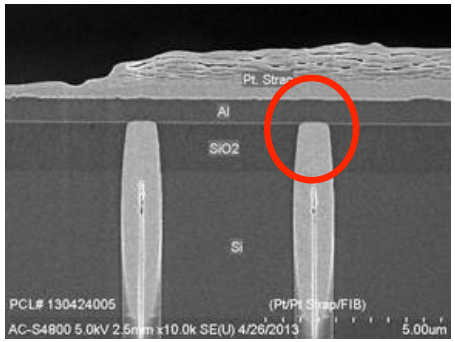
Integrated Circuits (cont.)

Status of 3D-IC activities:

- good results on individual chips
- 3D bonding misalignment up to ~2.5μm on Cu-Cu – problem
- attachment of ROICs to sensors + tests with radiation – priority now

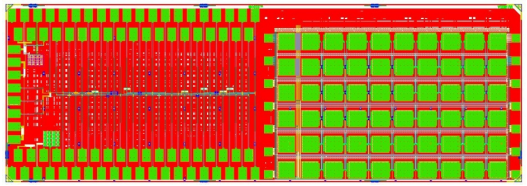


VIPIC1 (3D chip for X-ray Photon Counting); collaborating with BNL; 64x64 pixel @ 80μm pitch



SEM image of W TSVs providing contact to back-side Aluminum pad on VIPIC1

65nm (HL-LHC)



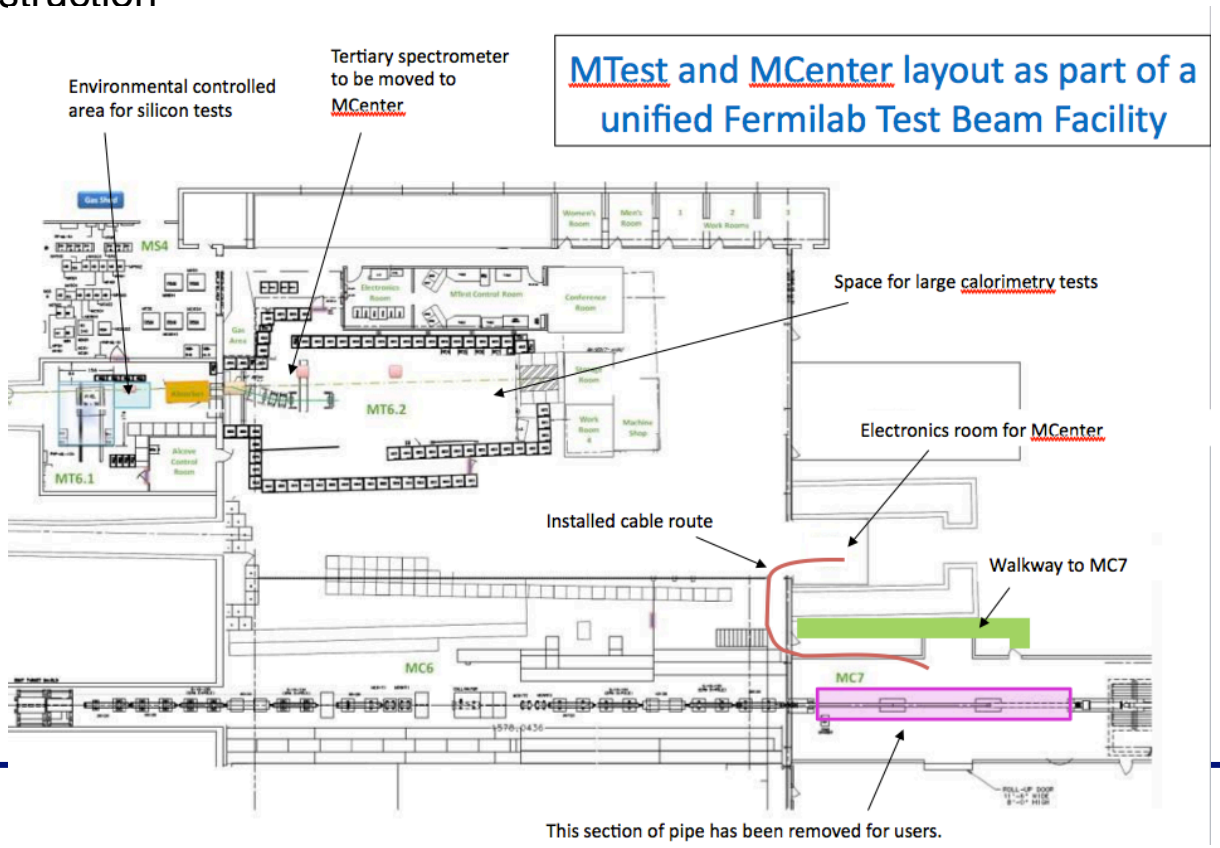
First Fermilab submission in 65nm MPW April 2013, 2x6mm^2 TSMC CMOS test struct.: single devices: active and passive of various types and geometries

65nm process is a new direction for us, and will allow us to work on HL-CMS pixel and track triggering. Status is:

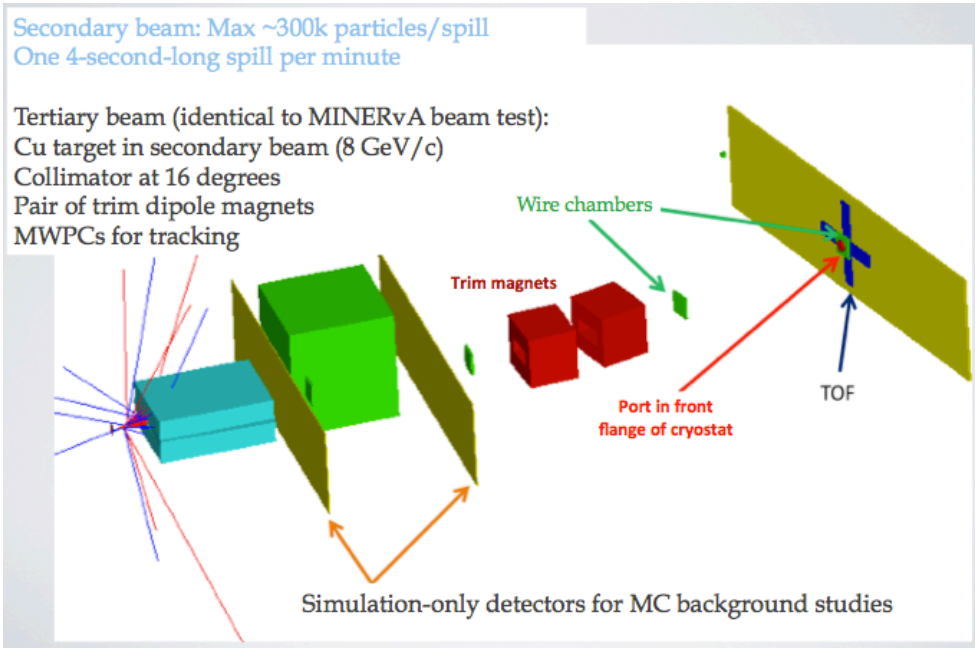
- *carrying out radiation hardness characterization of the process with target of up to 1Grad (irradiation at SNL on ^{60}Co source)*
- *need to meet obligations resulting from working in collaborations (CERN, LBL, INFN, and others).*
- *high costs: process and software tools for design*

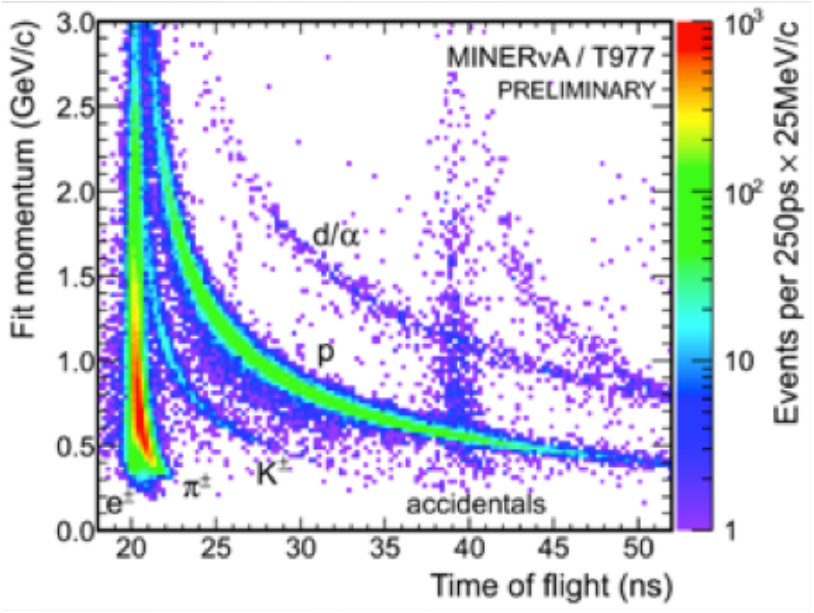
Progress in Facilities: The New MCenter Beamline for Fermilab Test Beam Facility (FTBF)

- We are waiting on official radiation safety assessment
- 4 magnets have slow water leaks–will replace these before turn-on
- Tertiary beam moved to MCenter user area for low momentum tests of liquid argon reconstruction



LARIAT = 'Liquid Argon In A Testbeam'





Beam will have very low rate, (10 events/spill) but have a quite varied particle content and very good particle i.d.

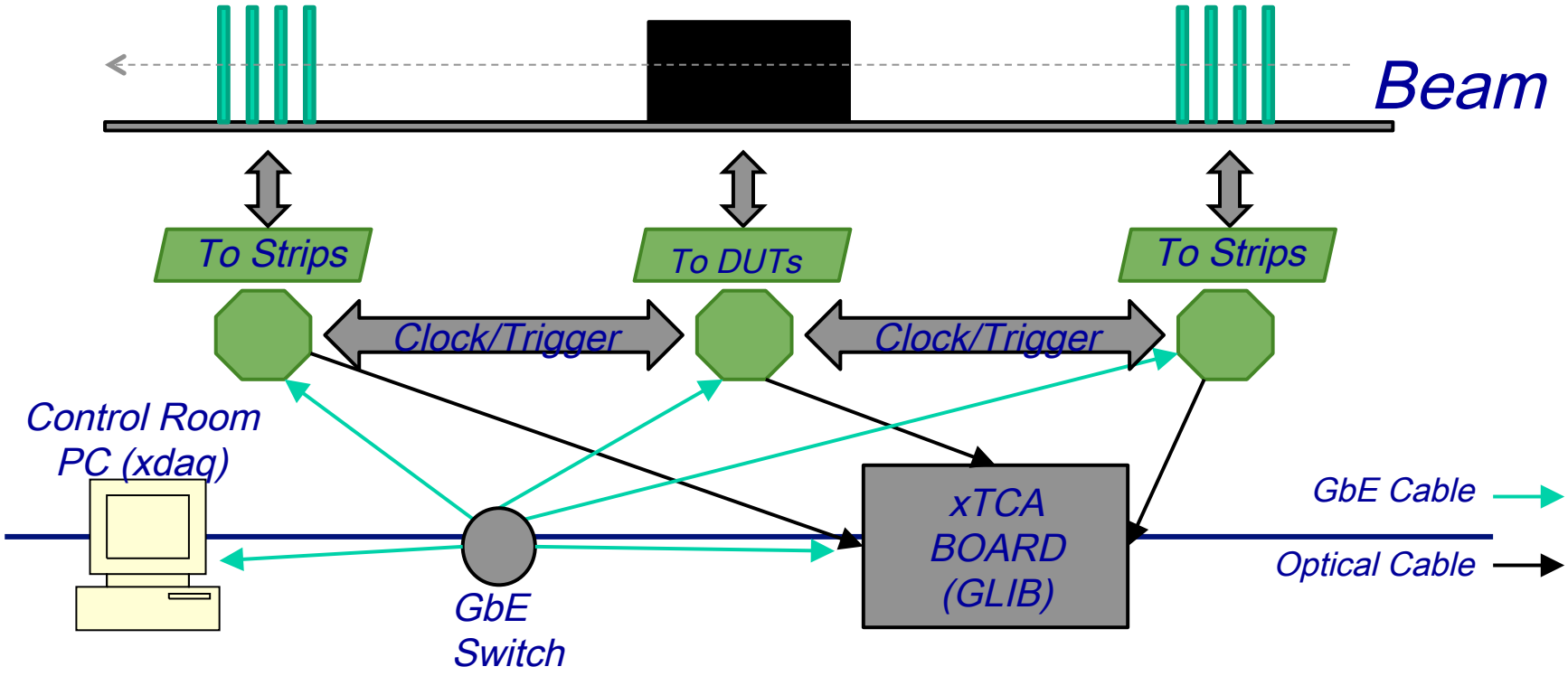
Where else in the U.S. could you test detectors with low energy kaons? – very relevant for proton decay

Silicon Strip Telescope for FTBF

The Detector Instrumentation Group of ESE/SCD in collaboration with Purdue University will commision a new strips telescope when the beam returns this summer. The telescope will be available to provide precision tracking for users as part of the Fermi Test Beam Facility.

• Telescope DAQ includes CAPTAN (Fermi design), MicroTCA GLIB (CERN design), and xdaq (CMS software framework) and will leverage past experience of CMS pixel telescope and CAPTAN DAQ:

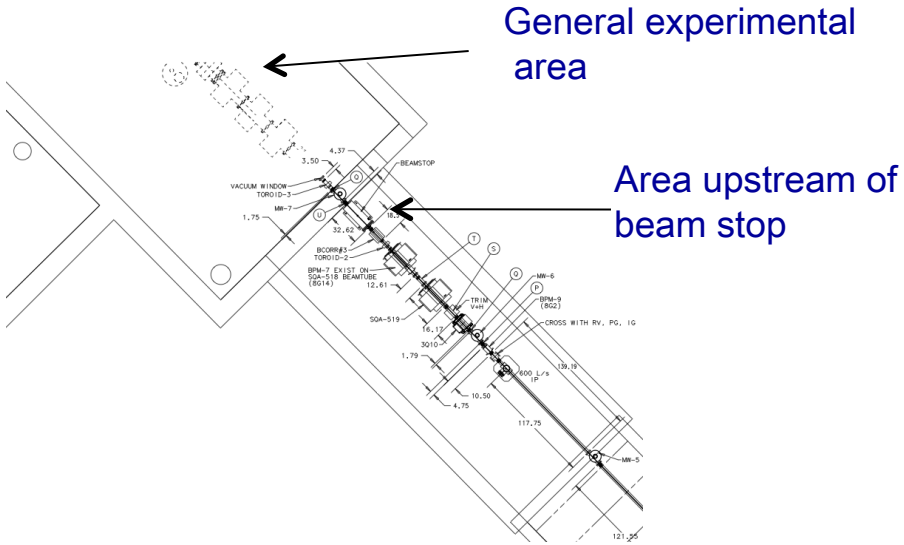
• Features: up to 16 planes with 60 micron D0 strip sensors, large active area (up to 8cm x 8cm, 25x area of pixel telescope), ~5 micron resolution anticipated, real-time track reconstruction in MicroTCA form factor. The strip redout chip is the FSSR2, which was designed at FERMILAB for the BTeV strip detector.



New R&D Irradiation Facilities

- A new area is being developed in the area upstream of the target for the MTest beamline, to support high intensity tracking groups.
- Flux will be ~1E12 / minute

- The MTA experimental hall has now accepted beam.
- It will likely be possible to support detector irradiation studies there
- Flux theoretically as high as 1E13/minute in the experimental hall, and higher upstream



Both areas will receive requests this year